CRACKING THE ICE ON ARCTIC OIL AND GAS EXPLORATION

ASSESSING THE ENVIRONMENTAL AND FINANCIAL FEASIBILITY OF ARCTIC OIL AND NATURAL GAS EXPLORATION

By

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Abstract

The Arctic, abundant in hydrocarbon resources, has been considered by the oil and gas industry to be the next big play. The potential resources are expected to challenge if not trump those available in the Middle East. As the arctic regions melt due to a warming climate, the previously treacherous and inaccessible regions are suddenly enticing enough to allow exploration for the very hydrocarbon resources that are largely responsible for the warming trends, creating the so-called Great Arctic Paradox. The paradox increases pressure to choose between competing goals—reduce climate change impacts or increase energy independence and expand energy supply outside of OPEC nations. These tensions are not new, and indeed are playing out in the United States in a variety of other arenas including in debates over hydraulic fracturing and offshore oil leasing off the East Coast of the U.S. However, the fragile nature of the Arctic ecosystem and the numerous state and non-state actors in the Arctic makes these tensions even more acute.

In this Master's Project I highlight these tensions and assess the economic and ecological feasibility and desirability of oil and gas exploration and extraction in the Arctic. To do this I review the climate science and ecology of the Arctic environment and how this is likely to be impacted by oil and gas exploration. I then examine the economic drivers of demand for Arctic energy, in particular forecasts for prices for oil and gas and for competing energy sources. Finally, I examine several models of policy options to reduce climate impacts, translate these policies into impacts on prices for oil/gas, and assess what impact different policies might have on the desirability of Arctic energy exploration. Results of the analysis suggest that while Arctic oil and gas resources are abundant, the value of the unique Arctic ecosystem, combined with lower expected prices for oil and gas and expectations of climate policies that will further decrease demand for oil and gas, make the economic case for Arctic extraction weak.

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The Arctic, abundant in hydrocarbon resources, has been considered by the oil and gas industry to be the next big play. The potential resources are expected to challenge if not trump those available in the Middle East. As the arctic regions melt due to a warming climate, the previously treacherous and inaccessible regions are suddenly enticing enough to allow exploration for the very hydrocarbon resources that are largely responsible for the warming trends, creating the so-called Great Arctic Paradox. The paradox increases pressure to choose between competing goals—reduce climate change impacts or increase energy independence and expand energy supply outside of OPEC nations. These tensions are not new, and indeed are playing out in the United States in a variety of other arenas including in debates over hydraulic fracturing and offshore oil leasing off the East Coast of the U.S. However, the fragile nature of the Arctic ecosystem and the numerous state and non-state actors in the Arctic makes these tensions even more acute.

This study investigates the major factors at play in facilitating and inhibiting the development of Arctic oil and gas resources through an analysis of three basic components: (a) the environmental considerations, (b) projections for global energy markets into the future, and (c) the political arena that will ultimately be coming to terms with increasing fossil fuel use and climate change impacts.

Climate and Environmental Concerns:

The Arctic environment is a unique and captivating place abundant with biological activity and life. While the region is very small compared to the entire earth's surface and is occupied by only a few people from only eight countries, the Arctic is heavily impacted by and impressed up on by those outside the region. On a global scale, the arctic represents the greatest of climate change impacts, and exhibits the paradox of the decision to burn fuels and or save the environment. Regionally the Arctic is linked by cultures, by migratory animals that are heavily adapted to the polar climate, as well as the massive hydrocarbon resources. If one country were to become active within their region effects could very easily be felt throughout. These effects are very concerning considering on the individual national level significant infrastructure is lacking to properly and safely support these extractive industries.

Energy Market Projections:

The energy market projections into the distant future are clear about one thing, more energy will be needed to drive a growing population that is seemingly insatiable for development. However, which energy resources are favored for development are highly tied to the current prices for developing these resources. If prices are high then suddenly riskier or more technologically expensive projects are enticing enough to develop, and also, if prices are to drop to low values, then the market reevaluates the current projects and favors those that are less expensive to develop and are safer commitments.

Policy Uncertainties:

Finally the policies that develop in the near and distant future to combat climate change are unclear and possibly unrealistic. While it may be a great exercise to model what a perfect world would look like in addressing the burning of carbon intensive fuels, if the international political systems are not cooperating accurately to stimulate successful and beneficial change, then the models are without significance.

Concluding Findings:

The environmental concerns of developing arctic hydrocarbon reserves are great because of risks posed to ecologically and biologically sensitive regions, preexisting challenges from climate change, and other possible negative impacts from human development. As well as countries within the Arctic are simply unprepared to respond to an event in the face of a disaster such as an oil spill. The energy market will need hydrocarbons well into the future, but in a world where we're to responsibly consider our energy consumption with the impacts of climate change, attentions are expected to shift away from the expensive and risky Arctic reserves. And finally, with an uneasy playing field due to unclear international policy regimes, further disincentives exist for expensive and risky investments. In evaluating the facilitating incentives and inhibiting concerns of the Arctic hydrocarbon reserves, it is in the collective global interest if we all left the Arctic hydrocarbons alone.

Approved

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Introduction to the Arctic

The Arctic Circle is drawn at the 66°33′45.7″ parallel, encircling a region that is only 6% of the total Earth's surface. A third of the Arctic is above sea level, another third is within the continental shelves of eight countries in shallow (up to 500 meter) water depths, and the final third is a deep ocean that has historically been covered by thick sea ice. The area that is the Arctic lies within the national boundaries of eight countries: Norway, Sweden, Finland, Russia, the Unites States, Canada, Denmark, and Iceland.

A home to resilient indigenous communities, the Arctic is a region rich with biodiversity and natural wonders. Though no system exists within a vacuum, the heavily adapted arctic has long been experiencing outside stressors. Threats such as air and water contamination, over fishing practices, habitat alterations and pollution from resource extraction developments, increasing pressures on land resources due to growing human populations all individually have the potential to overwhelm the inherent adaptive capacity of the arctic and its ecosystems.[1] As international attentions turn towards the Arctic for expanding extractive resource development, tourism, and international shipping, careful considerations should be taken to not overwhelm and destroy a place inherently unique and irreplaceable.

In many regions of the circumpolar north, exploration of oil and gas reserves are already a major economic driver, so much so that investigations are fully under way to determine if and how these practices can be replicated in other arctic areas.[2] However the end result of the extractive activities is giving some pause. Increased use of fossil fuels further accelerates climate change making the Arctic's climate, weather, and ice conditions increasingly less predictable.[3] As mentioned by the National Commission on the BP Deepwater Horizon Oil Spill "the stakes for drilling in the U.S. Arctic are raised by the richness of its ecosystems."[4]

[1] Arctic Climate Impact Assessment, "Impacts of a Warming Arctic-Arctic Climate Impact Assessment," *Impacts of a Warming Arctic-Arctic Climate Impact Assessment, by Arctic Climate Impact Assessment, Pp. 144. ISBN 0521617782. Cambridge, UK: Cambridge University Press, December 2004.* 1 (2004), http://adsabs.harvard.edu/abs/2004iwaa.book.....A%EF%BF%BD%C3%9C.
[2] Kamrul Hossain, Timo Koivurova, and Gerald Zojer, "Understanding Risks Associated with Offshore Hydrocarbon Development," in *Arctic Marine Governance* (Springer, 2014), 159–76.
[3] Hossain et al.Ibid.
[4] National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, "National Commission on the BP Deepwater Horizon Spill and Offshore Drilling," July 25, 2011, United States, http://digital.library.unt.edu/ark:/67531/metadc132999/.

While the hydrocarbon resources are valuable and plentiful, whether or not they are worth the expensive exploits is unclear. Arctic offshore drilling is considered to be greatly more expensive than most oil and gas extraction in other regions of the world due to the harsh, frigid and remote conditions of the Arctic.[5] These challenges require the use of advanced technologies and enhanced safety measures – further increasing the prices to operate and further distancing the companies from profitable returns.

This study investigates the major factors at play in facilitating and inhibiting the development of Arctic oil and gas resources through an analysis of three basic components: (a) the environmental considerations, (b) projections for global energy markets into the future, and (c) the political arena that will ultimately be coming to terms with increasing fossil fuel use and climate change impacts.

[5] Hossain, Koivurova, and Zojer, "Understanding Risks Associated with Offshore Hydrocarbon Development."

Methods for Analysis

To understand the Arctic environment in which these exploration and extraction activities are expected to take place, I examined current literature to gauge the current status and predicted futures of the Arctic environments. The following sources were used: Managing the Future in a Rapidly Changing Arctic: A report to the President[6], IPCC, 2007: Summary for Policymakers[7]. To understand the implications that oil and gas development may have on the arctic environment, careful attention was paid to studies conducted by the Marine Geospatial Ecology Lab at Duke University directed by Dr. Patrick Halpin to study the overlap of spatial and temporal ecologically and biologically sensitive areas (EBSA) and hydrocarbon reserves. The amount that these regions overlap predicts the amount extractive practices could impact the health and security of the ecological systems. In the case of a disaster or a worst-case scenario involving an oil spill I reviewed the National Academies Press report: Responding to Oil Spills in the U.S. Arctic Marine Environment[8].

To understand the motivations for or against arctic energy resources I first examined literature sources that describe the size of the possible hydrocarbon reserves. The resources used were: Assessment of Undiscovered Oil and Gas in the Arctic[9], Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle[10], and Understanding Risks associated with Offshore Hydrocarbon Development.[11] To understand the international demand markets I used three reports that examine current trends of energy supply and demand and make projections out into the future. The reports examined are: ExxonMobil Outlook for Energy: A view to 2040[12], Shell Energy Scenarios to 2050[13], and the World Energy Outlook 2014[14]. To determine the ways in which energy markets may shift, possibly preferring substitutes such as other hydrocarbon resources or towards more efficiently

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[6] Joel P. Clement, John L. Bengtson, and Brendan Patrick Kelly, *Managing for the Future in a Rapidly Changing Arctic: A Report to the President* (Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska, 2013).
[7] Susan Solomon et al., "IPCC, 2007: Summary for Policymakers," *Climate Change*, 2007, 93–129.
[8] *Responding to Oil Spills in the U.S. Arctic Marine Environment*, accessed March 5, 2015, http://www.nap.edu/catalog/18625/responding-to-oil-spills-in-the-us-arctic-marine-environment.
[9] Donald L. Gautier et al., "Assessment of Undiscovered Oil and Gas in the Arctic," *Science* 324, no. 5931 (May 29, 2009): 1175–79, doi:10.1126/science.1169467.
[10] "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle," accessed March 5, 2015, http://www.usgs.gov/science/cite-view.php?cite=2284.
[11] Hossain, Koivurova, and Zojer, "Understanding Risks Associated with Offshore Hydrocarbon Development."
[12] *The Outlook for Energy*, accessed February 24, 2015, http://corporate.exxonmobil.com/en/energy/energy-outlook.
[13] "Shell Energy Scenarios to 2050 - Shell Global," accessed February 24, 2015, http://www.shell.com/global/future-energy/scenarios/2050.html.
[14] IEA, *World Energy Outlook 2014* (http://dx.doi.org.proxy.lib.duke.edu/10.1787/weo-2014-en, 2014).

burning resources, these three reports were examined again: ExxonMobil The Outlook for Energy: A view to 2040[15], Shell energy scenarios to 2050 [16], World Energy Outlook 2014[17]. The final examination is of the financial feasibility of the Arctic resources, conducted by examining other plays to determine the relative costs and projections of what would be reasonable prices per barrel, the resources that describe this are the Arctic oil and Natural Gas Resources – Today in Energy - EIA[18], and the World Energy Outlook 2008[19].

Policy with respect to climate change, now and into the future, will either facilitate or greatly hinder the development of hydrocarbon resources globally. How these play out will have direct influences on whether or not the Arctic is seen as a profitable and worthwhile venture, but there is currently a great deal of uncertainty. In understanding the regulatory uncertainties several resources are examined that both describe the current regulatory gaps and offer suggestions for regulatory or policy frameworks into our future. First Donald Boesch : Deep-water drilling remains a risky business[20], and The BP Gulf Spill – Four years later statement [21] are used to examine the ways in which the offshore regulatory frameworks and technical abilities have been reshaped as a result of the BP Horizon Macondo well blowout. Then analysis of Arctic offshore development is conducted with resources from the Climate Change 2007: Impacts, Adaptation and Vulnerability[22], Addressing the Gaps in Arctic Governance[23], and Center for American Progress, Putting a Freeze on Arctic Ocean Drilling. America's Inability to Respond to an Oil Spill in the Arctic[24]. This is followed by an analysis of policy predictions

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[15] *The Outlook for Energy*.
[16] "Shell Energy Scenarios to 2050 - Shell Global."
[17] IEA, *World Energy Outlook 2014*.
[18] "Arctic Oil and Natural Gas Resources - Today in Energy - U.S. Energy Information Administration (EIA)," accessed January 28, 2015, http://www.eia.gov/todayinenergy/detail.cfm?id=4650.
[19] Fatih Birol, "World Energy Outlook," *Paris: International Energy Agency*, 2008, http://vnk.fi/tiedostot/julkinen/talousneuvosto/muistiot/TN-esitykset_14-04-07.pdf.
[20] Donald Boesch, "Deep-Water Drilling Remains a Risky Business," *Nature* 484, no. 7394 (April 17, 2012): 289–289, doi:10.1038/484289a.
[21] "2014 Statement by the Co-Chairs » Oil Spill Commission Action," accessed March 6, 2015, http://oscaction.org/2014-statement-by-the-co-chairs/.
[22] "Scenario Analysis and Analysis of Stabilisation Targets: Assessing Key Vulnerabilities and the Risk from Climate Change," accessed February 24, 2015, http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch19s19-4-2-2.html.
[23] "2014 Statement by the Co-Chairs » Oil Spill Commission Action."
[24] Kiley Kroh, Michael Conathan, and Emma Huvos, *Putting a Freeze on Arctic Ocean Drilling* (Center for American Progress, February 2012), http://www.americanprogress.org/wp-content/uploads/issues/2012/02/pdf/arcticreport.pdf.

from energy projections from the Shell Energy Scenarios to 2050 [25] and World Energy Outlook 2014[26]. Final regulatory analysis is through an analysis of the Polarisk, Top Polar Risks 2015[27] and the current unfolding Arctic Rule through the US agencies of BOEM and BSEE.

Additional policy considerations focus on the varying projections of co2 pricing schemes. This analysis is conducted using energy projections from the World Energy Outlook 2014[28], and Shell energy scenarios to 2050[29]. These projections are compared to current co2 prices.

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[25] "Shell Energy Scenarios to 2050 - Shell Global."
[26] IEA, *World Energy Outlook 2014*.
[27] "Top Polar Risks 2015 — Free Report by POLARISK," *POLARISK Group*, accessed February 24, 2015, http://www.polarisk-group.com/blog/top-polar-risks-2015.
[28] IEA, *World Energy Outlook 2014*.
[29] "Shell Energy Scenarios to 2050 - Shell Global."

Climate and Environmental Concerns

When discussing the impacts of a global warming trend on the Arctic a common misconception is that as the sea ice continues to disappear the region will soon if not immediately become available for development. This notion completely disregards the conditions that are inherent within the arctic regions – conditions that make any sort of development a challenge without the added complexities caused by a warming climate. During the winter months some common characteristics include months of polar darkness, temperatures averages of -40 degrees Celsius, occurrences of powerful storms, and a high frequency of "white out" conditions due to wind-blown snow.[30] [31]During the summer months the temperatures are slightly warmer where summer averages is 0 degrees Celsius, and low-level clouds and fog are commonly experienced reducing visibility. These challenges are not expected to disappear in the near future; rather they are expected to be further complicated as the region experiences unpredictable changes.

Global Climate warming has caused polar temperatures to increase a rate that is almost twice the global average in the past 100 years.[32] The image in Figure 1 describes a 50% decrease in the old multiyear sea ice of the Arctic. It is believed that the older thick ice acts as a buffer for short-term atmospheric changes; as the multi-year ice melts it is expected that there will be a greater abundance of smaller thinner ice sheets.

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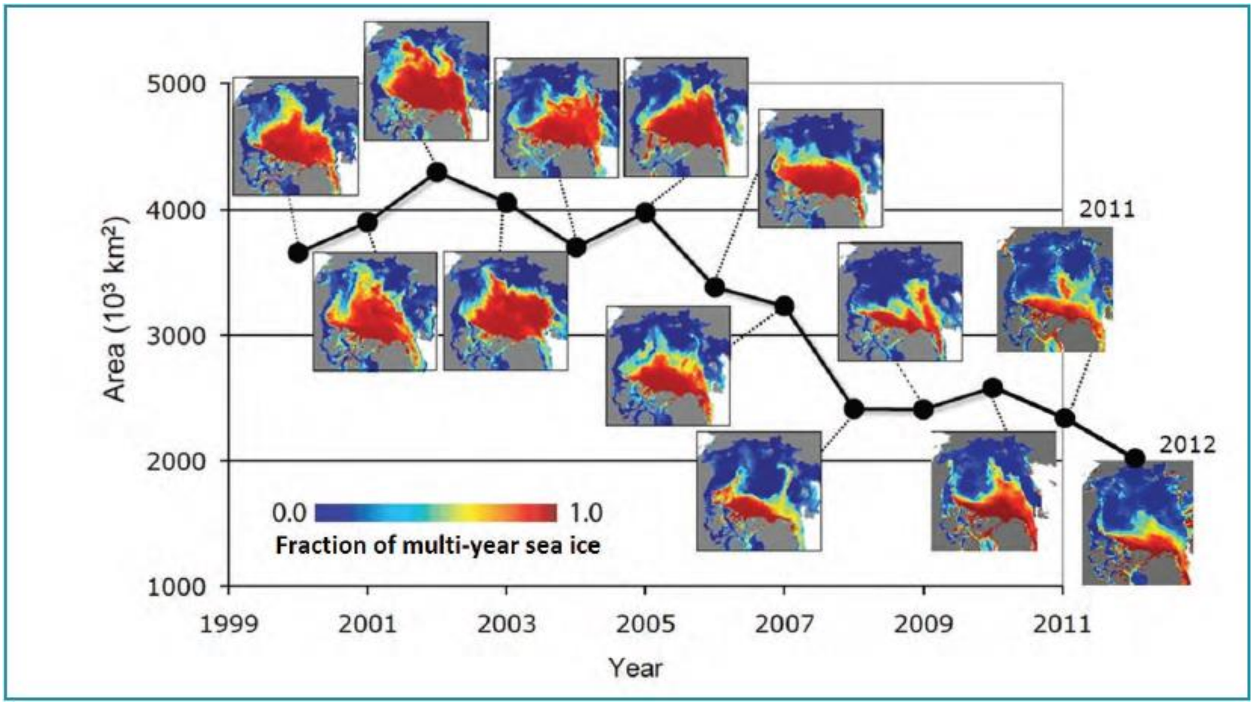
[30] Leslie E. Holland-Bartels and Brenda S. Pierce, *An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska* (US Department of the Interior, US Geological Survey, 2011), http://66.160.145.48/coms/anw/pdfs/27/Holland-Bartels_USGS_presentation.pdf.

[31] "Polar Discovery :: Comparing the Poles :: Weather," accessed April 23, 2015, http://polardiscovery.whoi.edu/poles/weather.html.

[32] Solomon et al., "IPCC, 2007."

Figure 1: Changes in Multi-year Sea Ice of the Arctic Region



Holland-Bartels & Pierce, 2011

Decreasing multiyear sea ice is expected to force the arctic regions be more sensitive to warming trends as a whole[33]. Environmental changes that are currently being experienced as a result of a warming climate and are expected to increase in intensity include warmer air and ocean temperatures, ealeir spring snowmelt, accellerated coastal erosion, and permafrost degredation.[34] Of all the areas on Earth, the arctic's climate projections consistenly show a pronounced sensitivity to greenhouse gasses primarily due to the snow and ice albedo-temperature feedback.[35]

With shortening winter season's winter roads will be available for shorter time spans, potentially forcing transportation of goods from terrestrial routes into the ocean. While the Arctic Ocean may become free of multiyear ice in a few years, the ocean will then become littered with a greater abundance of smaller icebergs, threatening polar shipping routes. Scientists and observers have long described ways in which dramatic reductions in sea ice, changing weather conditions, and thawing permafrost has caused a cascade of negative effects. Implications of these changes include drastically

[33] Clement, Bengtson, and Kelly, *Managing for the Future in a Rapidly Changing Arctic*.
[34] Solomon et al., "IPCC, 2007."
[35] Holland-Bartels and Pierce, *An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska*.

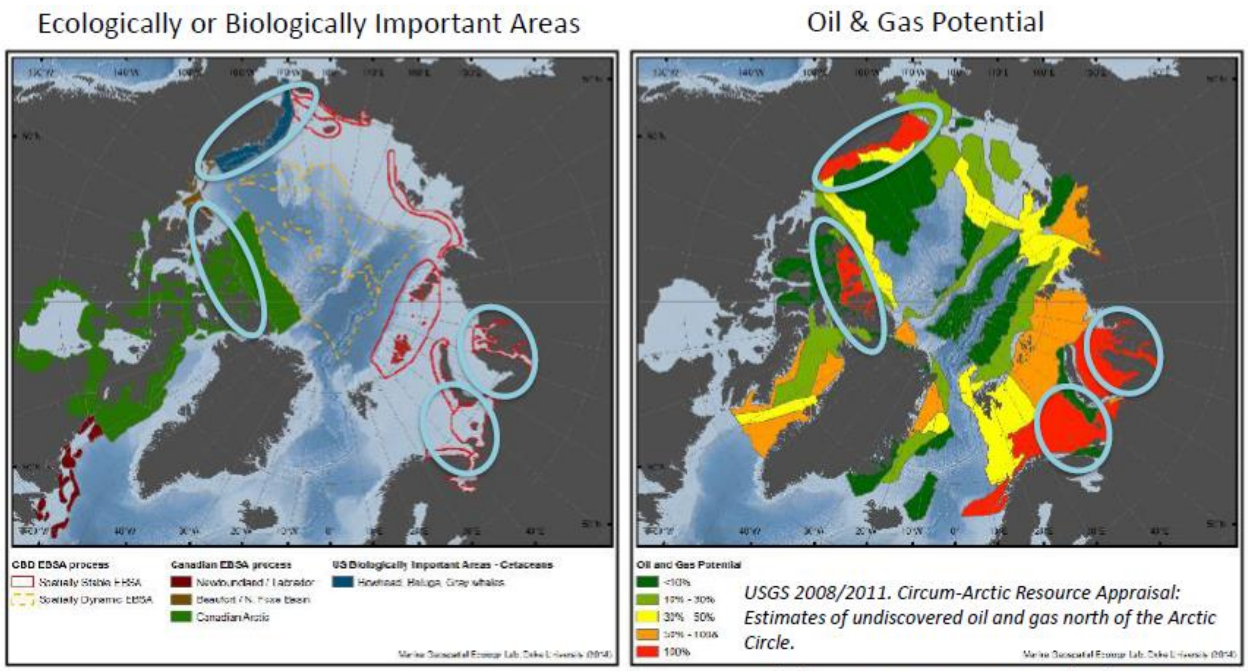
eroding coastlines threatening villages and facilities, a loss of wildlife habitat leading to ecosystem instabilities, which all impact the subsistence living and social needs.[36]

Warming trends are especially concerning for the indigenous wildlife that is so highly adapted to the harsh arctic conditions that have since been the norm.[37] Projected climate changes will undoubtedly stress these highly adapted biological systems. Species of concern that have already been listed on the United States Endangered Species List include the Polar Bear, the Ringed Seal and the Bearded Seal; all three of these species use the thick multiyear ice as their primary habitat. Additionally northern shifts of species distributions have been described to be currently occurring yet how these shifts will impact and affect the food webs is unknown.[38] As entire ecosystems, from seafloor organisms to higher trophic predators make northern shifts all livelihoods are at risk.

To understand the impacts that oil and gas exploration will have on Arctic Environments, studies conducted by the Halpin lab at Duke University study the overlap of spatial and temporal ecologically and biologically sensitive areas (EBSA) and hydrocarbon reserves. Ecologically and biologically significant areas are regions that meet the descriptions of the UN convention on biological diversity ecology or biologically significant area criteria. Through consolidating research conducted by international partners in the U.S., Russia and Canada, studies conducted by the Marine Geospatial Ecology Lab at Duke University directed by Dr. Patrick Halpin have analyzed the spatial and temporal ecological and biological sensitive areas (EBSA) and likelihood of high value hydrocarbon reserves and overlaid them with the regions determined by the USGS Circum-Arctic Resource Appraisal: Estimates of undiscovered oil and gas north of the Arctic Circle. The amount that these regions overlap predict the amount extractive practices could impact the health and security of the sensitive and important environmental systems. The following figure represents the findings of this study:

Figure 2: Overlaid Ecologically and Biologically Important Areas and Oil and Gas Potential

[36] Clement, Bengtson, and Kelly, *Managing for the Future in a Rapidly Changing Arctic*.
[37] Holland-Bartels and Pierce, *An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska*.
[38] Clement, Bengtson, and Kelly, *Managing for the Future in a Rapidly Changing Arctic*.



"Assessment units (AUs) in the Circum-Arctic Resource Appraisal (CARA) color-coded by assessed probability of the presence of at least one undiscovered oil and/or gas field with recoverable resources greater than 50 million barrels of oil equivalent (MMBOE).

(Halpin & Cleary, 2014)

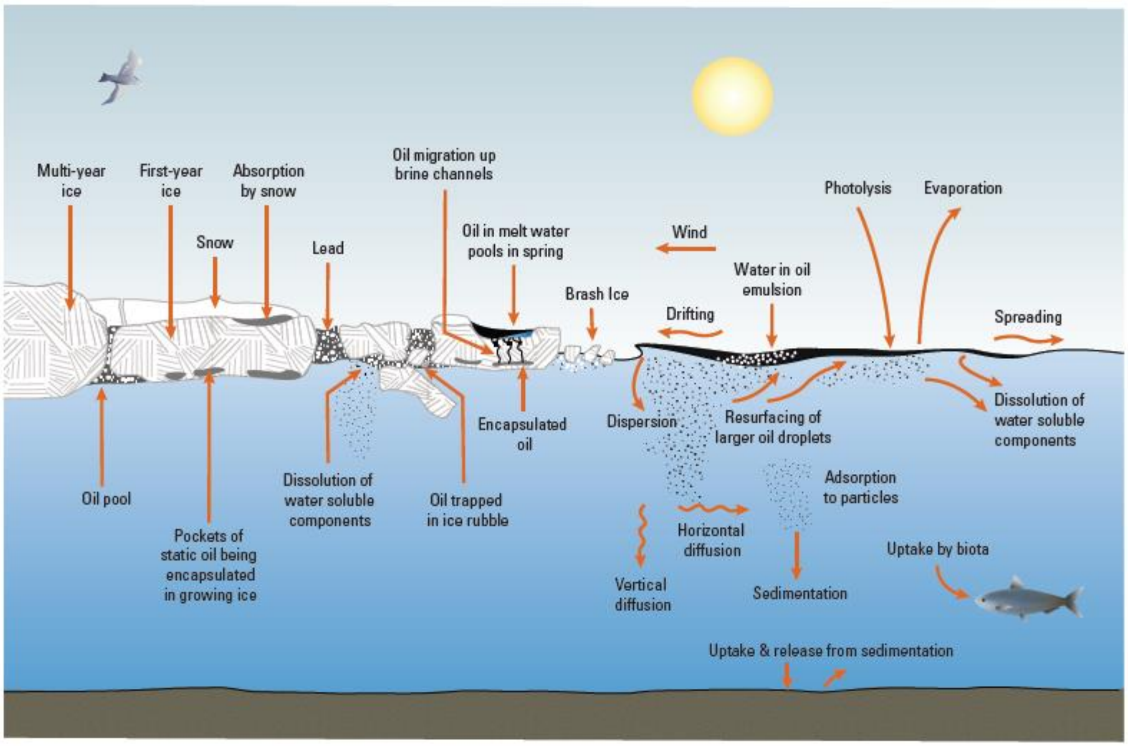
These studies have found that all of the high value oil and gas exploration regions are within regions with EBSA's. The percent overlap of all of the high value regions is 44.1%, and the percent overlap of 50-100% of the potentially highest value regions is 46.5%.[39] A potential impact that can be predicted is that as the Ice-free seasons are shifting there might be a more compressed time overlap between the hydrocarbon exploration and the timing of migratory species movements. The time period of the year that is most favorable to developments is the season when sea ice retreats, which is also the time when migratory species move into the region for feeding and spawning. Additionally, as these resources are developed, increased shipping of these resources and supplies are expected. This lab has shown that the emerging shipping lanes will pass through areas already identified as EBSA areas.[40]

In the case of a disaster or worst case scenario involving the spilling of oil into the arctic environment, laboratory experiments, field research, and practical experience have resulted in a body of knowledge on spilled oil response and recovery techniques, however the majority of these efforts have been concentrated in the temperate regions and less is known about the Arctic conditions. Processes

[39] Patrick Halpin and Jesse Cleary, "Ecologically or Biologically Significant Areas in the Arctic: Spatial and Temporal Overlaps with Expected Increases in Energy Exploration" (CAFF Congress, December 3, 2014), http://www.arcticbiodiversity.is/program/presentations/december-3/1030-1200/eco-charac-energy.
[40] Ibid.

that control oil behavior and weathering in Arctic conditions are described in the following figure, this image represents the ways in which oil is expected to behave within the arctic environment. As can be seen from the many different orange arrows oil in an arctic environment may experience a number of fates – of which many include becoming locked within ice sheets, snow, or heavily dispersed.

Figure 3: Arctic Oil Dispersion



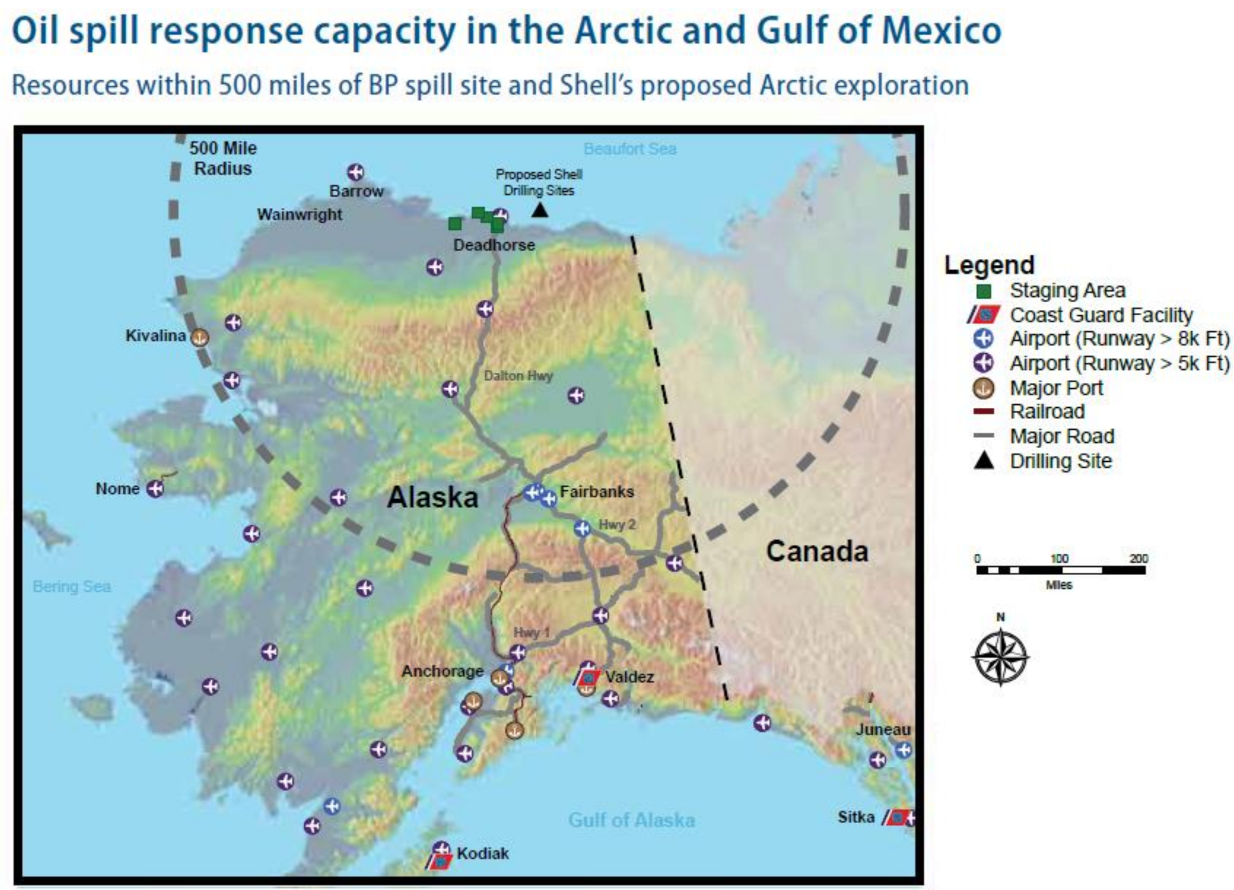
(Responding to Oil Spills in the U.S. Arctic Marine Environment, n.d.)

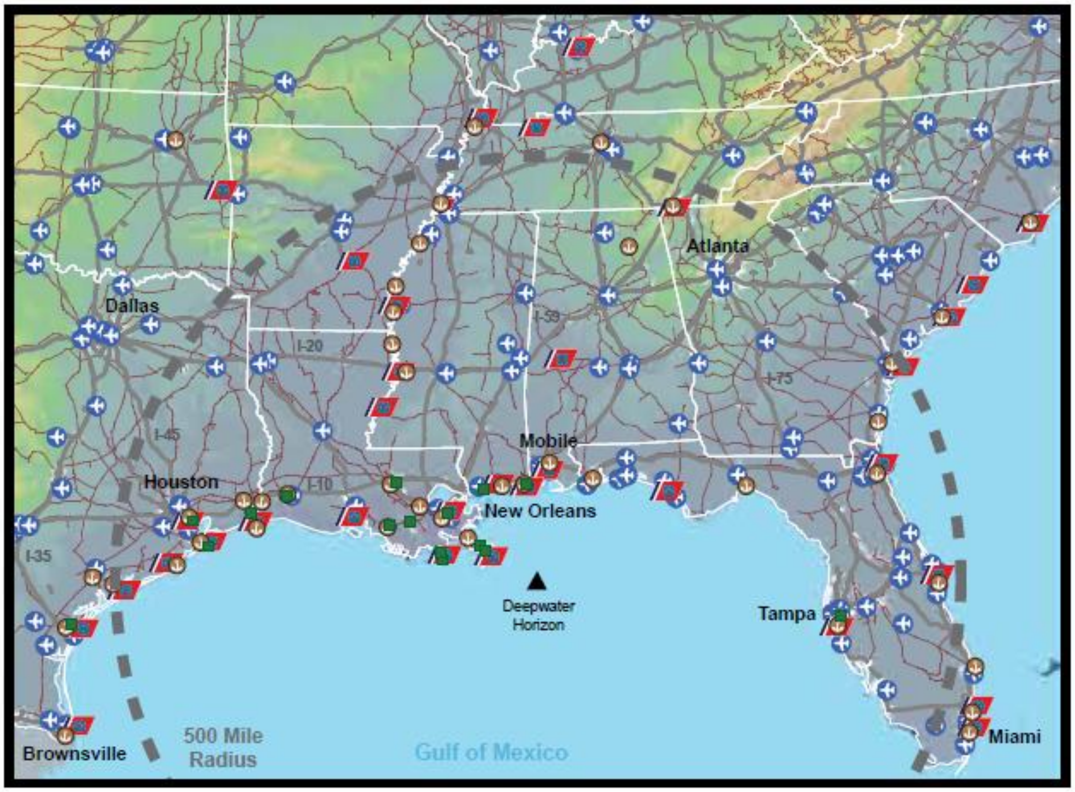
Key oil spill response capabilities include biodegradation (treating oil with dispersants), in situ burning, chemical herders, mechanical containment and recovery, detection and tracing, oil spill trajectory modeling, as well as "no response" techniques[41]. Except from the use of dispersants which can be used subsurface as seen in the Deepwater Horizon event, these technologies are largely limited to the water's surface. Anything that mixes or spreads beyond the mechanical ability to reach is largely irretrievable. As mentioned previously, these practices not been investigated within an arctic reference frame or successfully implemented to know which procedure is most effective in each sea-ice-oil interaction. In an absence of Arctic specific knowledge, the next best opportunity to learn, prepare for, and train for an oil spill in the Arctic, is an oil spill elsewhere, such as the BP Horizon event in the Gulf of Mexico.

[41] *Responding to Oil Spills in the U.S. Arctic Marine Environment*.

The infrastructure available to deal with a spill at the locations on the Northern Slope where Shell has proposed exploration, compared to the capabilities available in the Gulf to address the BP Horizon Deepwater blowout is largely disproportionate. The following figure displays the great difference in infrastructure and capabilities between the Alaskan Arctic region and the American coastline of the Gulf of Mexico:

Figure 4: Oil spill response capacity in the Arctic and in the Gulf of Mexico.





(“The Lasting Impact of Deepwater Horizon | Center for American Progress,” n.d.)

Immediately recognizable is the drastic sparseness of the resources in the Alaskan Arctic compared to those in the gulf. When an offshore oil spill occurs the first responders to the scene are the Coast Guard. In the Coast Guard facilities are well beyond the marked 500 mile distance – they’re almost twice that distance at the southern end of the state, well beyond a distance that is close enough to respond to an oil spill that would cause immediate human and environmental dangers. It is also important to note that despite the availability of all of these resources, the deep water horizon event spilled over 4.6 million barrels of oil when the well remained uncapped for almost four months of the summer of 2010. Given the blow out occurred in a region surrounded by the best of response capabilities, and on a calm day that basically presented the “best case” for oil spill clean-up response, still only a small percentage of the spilled hydrocarbons were recovered. While it is true that the Arctic drilling will be done in shallower conditions, with response capabilities and recovery resources to far away and the limited season open for drilling, even shallow water wells could leak for a long time.

In addition to the infrastructure limitations of the individual arctic nations, the ability to respond to neighborly disasters has not been developed. If an event were to occur outside of the Alaskan Arctic the capabilities of Americans to get on scene to respond is incredibly limited – as are the abilities of other arctic nations to respond. International cooperation has not yet been coordinated or negotiated[42].

While the Arctic regions are of main concern to this investigation, it is the global implications of climate warming that are expected to force policy action and motivate or disfavor arctic exploration. Trends presented by the Intergovernmental Panel on Climate Change have determined that a scenario of 450 parts per million is the tipping point that will push global warming above a 2 degree Celsius change and therefore past a point from which natural recovery is possible.[43] This 450 ppm is the point that international policy makers has as the the focal point of climate policy negotiations. Climate impacts beyond this point include sea level rise, coral bleaching, intensifying drought and resource scarcity.

With the goal of addressing climate change policy entrepreneurs will need to make decisions of energy usage. These considerations will influence the types of energy resources that will be developed, and the places from which those energy resources come from. Not all hydrocarbons are the same in the machinery used the difficulty in extraction, and in getting the product to market. Decisions on which hydrocarbons will come to market will be based on energy needs, prices for these different resources, and proximity to markets. The energy market projections into the future will largely help in determining if and when these Arctic hydrocarbons come into play.

[42] Ibid.
[43] "Scenario Analysis and Analysis of Stabilization Targets: Assessing Key Vulnerabilities and the Risk from Climate Change," 2.

Energy Market Projections

The Arctic has become of interest for the Energy industry largely because of the report Assessment of Undiscovered Oil and Gas in the Arctic[44]. This report published by the Unites States Geological Survey assessed the areas north of the Arctic Circle to find an estimated 30% of the world's undiscovered gas and 13% of the world's undiscovered oil.[45] The examined arctic provinces are listed in the following table, in ranked order of total mean estimated oil, gas, and natural gas liquids. This table allows for greater understanding of the relative quantities of hydrocarbon resources between each region.

[44] Gautier et al., "Assessment of Undiscovered Oil and Gas in the Arctic."
[45] Ibid.

Figure 5: Arctic provinces and their estimated hydrocarbon resources

Province Code	Province	Oil (MMBO)	Total Gas (BCFG)	NGL (MMBNGL)	BOE (MMBOE)
WSB	West Siberian Basin	3,659.88	651,498.56	20,328.69	132,571.66
AA	Arctic Alaska	29,960.94	221,397.60	5,904.97	72,765.52
EBB	East Barents Basin	7,406.49	317,557.97	1,422.28	61,755.10
EGR	East Greenland Rift Basins	8,902.13	86,180.06	8,121.57	31,387.04
YK	Yenisey-Khatanga Basin	5,583.74	99,964.26	2,675.15	24,919.61
AM	Amerasia Basin	9,723.58	56,891.21	541.69	19,747.14
WGEC	West Greenland-East Canada	7,274.40	51,818.16	1,152.59	17,063.35
LSS	Laptev Sea Shelf	3,115.57	32,562.84	867.16	9,409.87
NM	Norwegian Margin	1,437.29	32,281.01	504.73	7,322.19
BP	Barents Platform	2,055.51	26,218.67	278.71	6,704.00
EB	Eurasia Basin	1,342.15	19,475.43	520.26	5,108.31
NKB	North Kara Basins and Platforms	1,807.26	14,973.58	390.22	4,693.07
TPB	Timan-Pechora Basin	1,667.21	9,062.59	202.80	3,380.44
NGS	North Greenland Sheared Margin	1,349.80	10,207.24	273.09	3,324.09
LM	Lomonosov-Makarov	1,106.78	7,156.25	191.55	2,491.04
SB	Sverdrup Basin	851.11	8,596.36	191.20	2,475.04
LA	Lena-Anabar Basin	1,912.89	2,106.75	56.41	2,320.43
NCWF	North Chukchi-Wrangel Foreland Basin	85.99	6,065.76	106.57	1,203.52
VLK	Vilkitskii Basin	98.03	5,741.87	101.63	1,156.63
NWLS	Northwest Laptev Sea Shelf	172.24	4,488.12	119.63	1,039.90
LV	Lena-Vilyui Basin	376.86	1,335.20	35.66	635.06
ZB	Zyryanka Basin	47.82	1,505.99	40.14	338.95
ESS	East Siberian Sea Basin	19.73	618.83	10.91	133.78
HB	Hope Basin	2.47	648.17	11.37	121.87
NWC	Northwest Canada Interior Basins	23.34	305.34	15.24	89.47
MZB	Mezen' Basin	NQA	NQA	NQA	NQA
NZAA	Novaya Zemlya Basins and Admiralty Arch	NQA	NQA	NQA	NQA
TUN	Tunguska Basin	NQA	NQA	NQA	NQA
CB	Chuckhi Borderland	NQA	NQA	NQA	NQA
YF	Yukon Flats (part of Central Alaska Province)	NQA	NQA	NQA	NQA
LS	Long Strait	NQA	NQA	NQA	NQA
JMM	Jan Mayen Microcontinent	NQA	NQA	NQA	NQA
FS	Franklinian Shelf	NQA	NQA	NQA	NQA
Total		**89,983.21**	**1,668,657.84**	**44,064.24**	**412,157.09**

(Donald L. Gautier et al., "Assessment of Undiscovered Oil and Gas in the Arctic," *Science* 324, no. 5931 (May 29, 2009): 1175–79, doi:10.1126/science.1169467.)

This USGS study estimates that more than 70 percent of the mean undiscovered oil is in just five provinces: Arctic Alaska, Amerasia Basin, East Greenland Rift Basins, East Barents Basins, and West Greenland-East Canada. While more than 70 percent of the undiscovered natural gas is in three provinces: the West Siberian Basin, the East Barents Basins and Arctic Alaska. Additionally, the USGS estimates that over 84 percent of the undiscovered oil and gas reserves occur offshore at shallow water depths less than 500 meters.[46] The following map illustrates the regions that hold the greatest hydrocarbon reserves:

Figure 6: Map of greatest hydrocarbon reserves:

(Hossain, Koivurova, & Zojer, 2014)

The total mean undiscovered conventional oil and gas resources of the Arctic are estimated to be approximately 90 billion barrels of oil, 1,669 trillion cubic feet of natural gas, and 44 billion barrels of natural gas liquids[47]. While these resources are abundant in supply, whether they are in high enough demand and accompanied with high enough profits will determine whether or not the resources are explored and extracted.

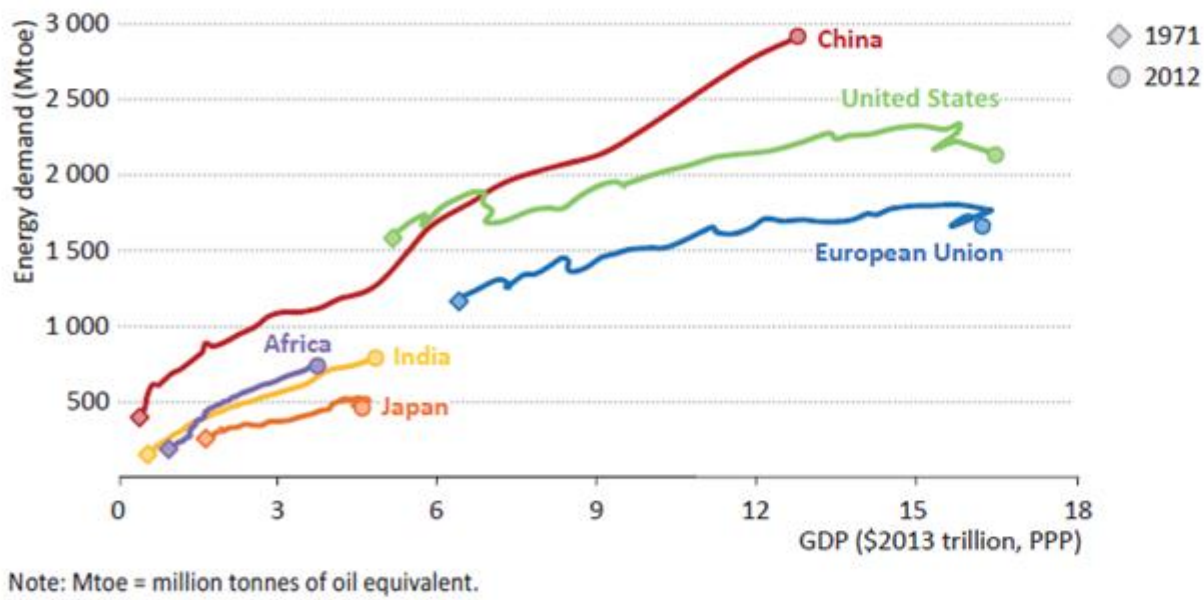
To date, the global energy demand has increased to meet the needs of a growing world population and growing GDP. This trend as displayed by the World Energy Outlook is expected to continue to meet

[46] "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle."

[47] "USGS Release: 90 Billion Barrels of Oil and 1,670 Trillion Cubic Feet of Natural Gas Assessed in the Arctic (7/23/2008 1:00:00 PM)," accessed September 19, 2014, http://www.usgs.gov/newsroom/article.asp?ID=1980#.VBxjZPldWSo.

not only growing populations but also an international move out of poverty. The following figure describes how energy demand and GDP have trended in the past.

Figure 7: Total primary energy demand and GDP in selected countries 1971-2012



(IEA, n.d.)

Projections into the future assume that this above trend will continue. If these projections are true, the World Energy outlook predicts an increase in energy demand of 37% by 2040[48]. Projections that describe the ways in which different regions demand energy and how that supply is met is greatly determined by the policies of the region and the price of the energy. Largely ignoring the different policies that are being presented in the following figure (these policy frameworks will be returned to in a later chapter of analysis), we can see several large trends emerge as a common factors. Drawing attention to the final two lines in the following table we can see that in most scenarios, the demand for hydrocarbons are expected to increase. Additionally the majority of the hydrocarbon use will be in the non-oecd countries, or the countries that are still developing, these countries have little other options other than to energize their development out of poverty through the use of hydrocarbons. Despite projections for improved energy efficiency, which will allow a higher level of energy satisfied per unit of

[48] IEA, *World Energy Outlook 2014*.

energy produced, all projections show that hydrocarbons will remain a large majority of the energy mix assuring the need for oil and gas into our near futures.

Figure 8: World primary energy demand by fuel and scenario (Mtoe)

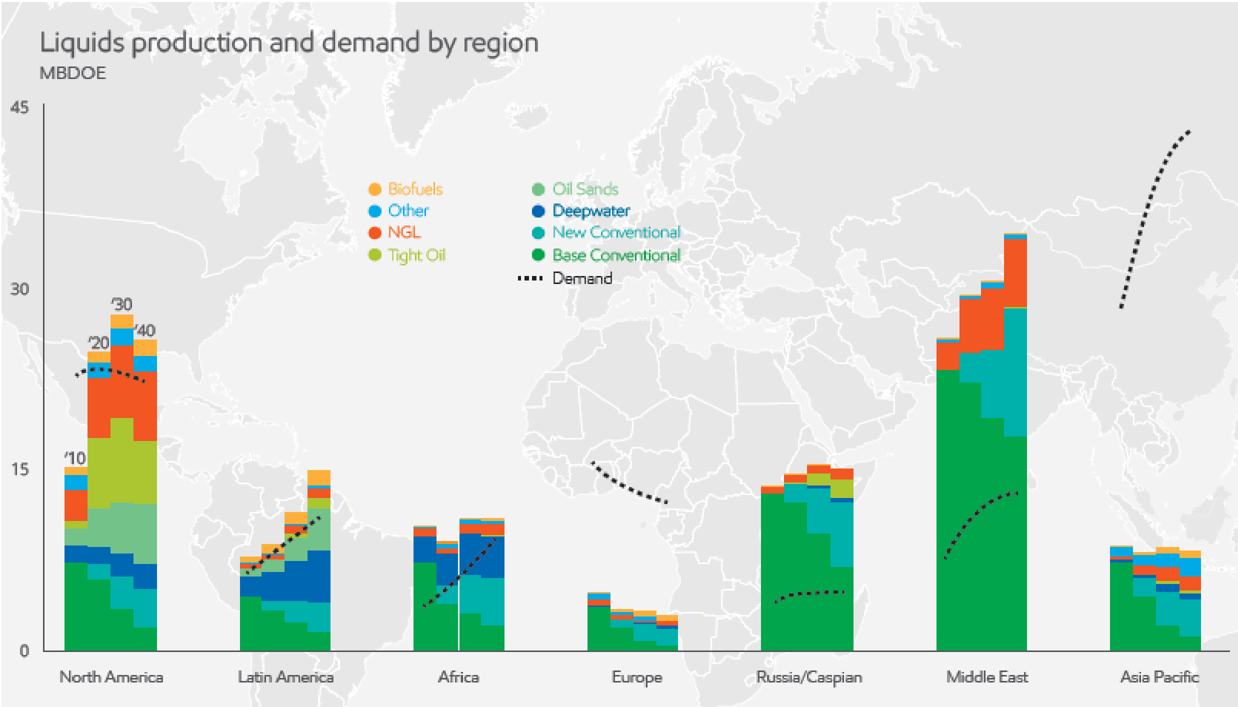
		New Policies		Current Policies		450 Scenario	
	2012	2020	2040	2020	2040	2020	2040
Coal	3 879	4 211	4 448	4 457	5 860	3 920	2 590
Oil	4 194	4 487	4 761	4 584	5 337	4 363	3 242
Gas	2 844	3 182	4 418	3 215	4 742	3 104	3 462
Nuclear	642	845	1 210	838	1 005	859	1 677
Hydro	316	392	535	383	504	392	597
Bioenergy*	1 344	1 554	2 002	1 551	1 933	1 565	2 535
Other renewables	142	308	918	289	658	319	1 526
Total	**13 361**	**14 978**	**18 293**	**15 317**	**20 039**	**14 521**	**15 629**
Fossil fuel share	*82%*	*79%*	*74%*	*80%*	*80%*	*78%*	*59%*
*Non-OECD share***	*60%*	*63%*	*70%*	*63%*	*70%*	*63%*	*68%*

* Includes traditional and modern uses of biomass. ** Excludes international bunkers.

(IEA, n.d.)

While Energy demands may be increasing in some regions, it's important to note that in other regions the energy demands are actually predicted to level off or to decrease. The following graph describes the a projection for changes in production and demand throughout the many regions of the world:

Figure 10: Liquids Production and demand by region



("The Outlook for Energy," n.d.)

While a lot of discussion has been on total energy demand we should be careful to notice that not every energy source is treated equally and it's not a simple conversion required to switch between energy types. Often time real concerns are over whether the resources are too costly to access – a concern that is very prevalent when considering the resources in the Arctic.

The IEA World Energy Outlook 2008 estimates that the costs of production and exploration of the many different Arctic cites varies greatly due to increasing distances from other existing fields and infrastructure[49]. In some of the most easily accessible locations for extraction these plots can be profitable at 35-40 dollars per barrel[50]. However in public comments made by Yevgeny Primakov a previous foreign and finance minister of Russia made recommendations to not hurry to develop Arctic oil projects stating that the costs of development are great enough to cause concern especially when compared to other cheaper plays available to the Russians. Primakov was quoted saying "Most [other] fields are already secured an acceptable return at a price of $60 dollars, and LUKOIL has said that production in Western Siberia is profitable even at $25, "he continued "Arctic offshore oil production is only profitable at an oil price of 100-120 dollars per barrel. Is it really worth boosting oil production on

[49] Birol, "World Energy Outlook."
[50] Ibid.

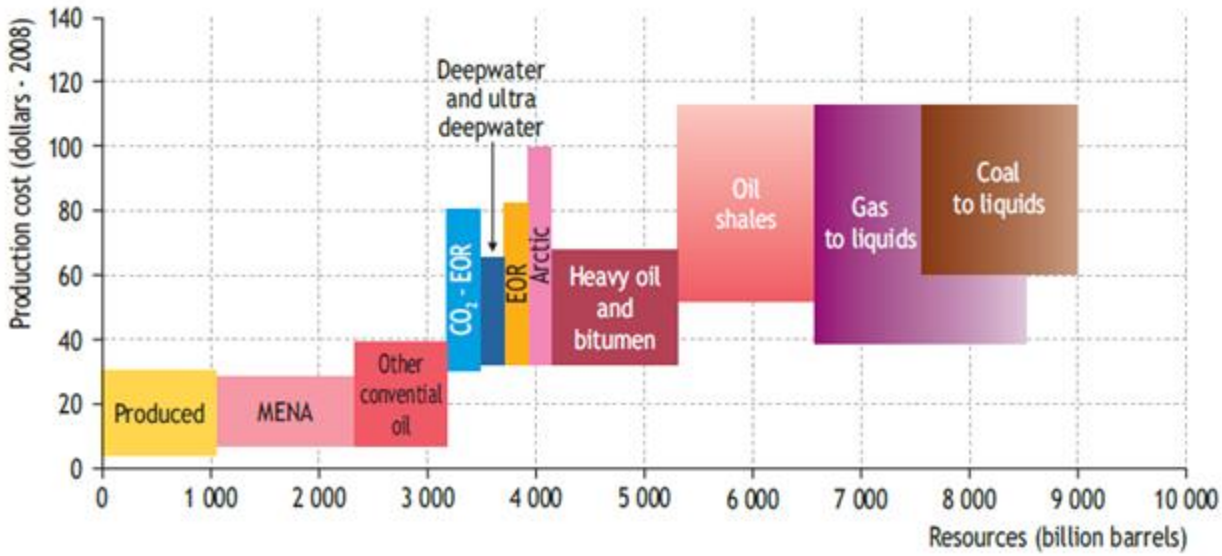
the shelf under conditions such as now?" Primakov later suggested that despite the importance of the region to Russia that they should not rush into development, given the current state of the economy he suggests a pause in development just like other Arctic countries citing the last drilling in the USA was done in 2003 and in Canada in 2005.[51]

Discrepancies in the profitability of arctic oil have been attributed to many different factors. The IEA report of $35-40 doesn't take into consideration the infrastructure, specialized machinery, and human capital costs. The costs of operating in the Arctic marine environment assume most if not all of the same costs that normal offshore operations assume; with additional provisions for additional operating costs associated with being in an extreme environment[52]. The US EIA found that "studies on the economics of onshore oil and natural gas projects in Arctic Alaska estimate costs to develop reserves in the Region can be 50-100 percent more than similar projects undertaken in Texas".[53] Several of the main obstacles to profits are due to the conditions of the operating within the arctic: technology and equipment would need to specifically develop for the frigid temperatures, poor soil conditions and melting permafrost requires additional site preparation to prevent equipment and structures from sinking. Distance from manufacturing centers and limited transportation and shipping requires equipment redundancy and a greater supply of spare parts to ensure reliability. Additionally higher compensation and wages would be required to incentivize employees to work in such isolated and inhospitable regions.[54]

The decision to explore and extract these resources will depend on the profitability of the resources as well as a comparison of the other resources available for production. The following figure shows a comparison of resource sizes and their relative prices.

[51] "Ex-Minister Suggests Pause in Russian Arctic Oil," *Barentsobserver*, accessed February 21, 2015, http://barentsobserver.com/en/energy/2015/01/ex-minister-suggests-pause-russian-arctic-oil-14-01.
[52] Birol, "World Energy Outlook."
[53] "Arctic Oil and Natural Gas Resources - Today in Energy - U.S. Energy Information Administration (EIA)."
[54] Ibid.

Figure 11: Long Term Cost Supply Curve



Note: The curve shows the availability of oil resources as a function of the estimated production cost. Cost associated with CO_2 emissions is not included. There is also a significant uncertainty on oil shales production cost as the technology is not yet commercial. MENA is the Middle East and North Africa. The shading and overlapping of the gas-to-liquids and coal-to-liquids segments indicates the range of uncertainty surrounding the size of these resources, with 2.4 trillion shown as a best estimate of the likely total potential for the two combined.

(Birol 2008)

The analysis conducted by the above figure suggests that the cost of exploiting conventional resources (excluding taxes and royalties) typically ranges from less than $10 to $40 per barrel. Analysis of the available resources led the IEA to predict that the Arctic resources could experience prices between $40 and $100 per barrel.[55]What can be misleading in the above figure is the oil shale uncertainty that existed in 2008 when this figure was created. Now those unknown of technologies have unlocked those productive reserves, overcoming the technological hurdle has made the resources more appealing than when this report was published. Also interesting to note in the figure is the price variability and the relative size of the arctic resources in comparison to the other global reserves. This figure suggests that the variability in price and small resource size in respect to other more easily accessible, more profitable, and larger plays may incentivize less investment in Arctic oil, and more investment in the other reserves.

A final consideration for evaluating the costs associated with Arctic oil and oil and gas exploration is less dependent on the actual technological costs, and more on the political costs of developing within a relatively pristine environment. Currently the Arctic is generating mass amounts of

[55] Birol, "World Energy Outlook."

attention from investors, politicians and the general public. On a global viewing platform, polar developments will be subjected to intense scrutiny especially in terms of sustainability and transparency. A great risk associated with the Arctic is that one negligent act that could happen at any time, in any part of the Arctic, which could potentially close the entire arctic for all future developments. A closure of the Arctic could lead to great losses in the form of stranded assets and in human capital. The people of the Arctic will be invested heavily in the success of any development, for a failure could bring societal and cultural destruction. In a report published by the consulting company POLARISK, "unsustainable developments" was considered one of the top polar risks for 2015.[56] Operations in the Arctic require the highest of technical ability; failure is simply not an option making the investment greater than just a financial one.

Additionally Polarisk warns that the main considerations for moving into the Arctic are actually not motivated by "economic rationales" but rather by geopolitics, citing sanctions against Russia as motivation for other Arctic nations to surge forward with arctic exploration now that Russians are stalled.[57] Similarly the Arctic could be seen as a secure or relatively safe region for hydrocarbon resources because it is a region with no ongoing conflicts that could potentially disrupt production. This concern is in reference to the October 1973 world oil crisis spurred by Arab members of petroleum producing countries banning shipments of oil to countries supporting Israel in the 1973 Arab-Israeli war.[58] While global prices for energy resources may provide a certain set of incentives for or against exploration, the geopolitical landscape may also provide its own influences.

[56] "Top Polar Risks 2015 — Free Report by POLARISK."
[57] Ibid.
[58] Hossain, Koivurova, and Zojer, "Understanding Risks Associated with Offshore Hydrocarbon Development."

Policy Uncertainties

Whether or not Arctic oil and gas resources will be explored and extracted will be greatly dependent upon global energy and climate change policies as well as the regulatory framework to prepare for disasters and or support hydrocarbon development. Currently there is slow movement towards a unifying and legally binding climate policy, however in several projections for energy supplies and demand into the future leading think tanks and agencies produced multiple scenarios that account for global policy uncertainties. Global warming is a trend that will not subside unless radical movements are made to stem the flood of greenhouse gasses into our atmosphere, how our international political regimes come to agreements to deal with the stresses of a warmer climate will cause a change in the demands for hydrocarbons. Dis-incentives for hydrocarbons would potentially alter the resources that are seen as most likely to develop citing profit margins and political and investment risks as the deterring factors. Additionally, little has been done to prepare for an oil spill in domestic and international Arctic waters, questions of technical ability, liability and financial responsibilities remain unanswered.

In the World Energy Outlook the IEA strongly believes decisions to commit capital to the energy sector are more often shaped by government policy measures and incentives, rather than by signals coming from competitive markets. [59] When examining projections for how the energy demands will be shaped into the future to 2040 they present three scenarios: Status quo, a New Policies Scenario, and a 450 Scenario. The changes that are modeled for in these varying scenarios are in reference to different CO2 pricing schemes that are enabled to curb hydrocarbon use and adjust greenhouse gas production.

The planned policies include measures to reduce air pollution from the use of coal and improve efficiency in China, a plan to cut power sector emissions and extend fuel economy and emission standards for heavy-duty vehicles in the United States, a proposed climate energy package in the European union and building code and fuel efficiency standards for passenger vehicles in India.[60] Despite these changes the New Policies Scenario is not expected to stay within the 2 degree Celsius change; it is only a projection of the status quo out to 2040. The New Scenarios plan is projected to experience co2 emission increase to 3.0 GT in 2040 – an increase that is predicted to correlate with a greenhouse gas concentration in the atmosphere to over 700 parts per million. The 450 Scenario is the plan that the International Energy Agency believes is necessary to be able to meet the determined level of 450 ppm.

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[59] IEA, *World Energy Outlook 2014*.
[60] Ibid.

For the 450 Scenario to be met, significant policies will be needed to force different regions to take account of their impact and decrease emissions.

Some of the greatest challenges in meeting the goals of these models include mobilizing private investors to acquire the capital required investments in other new technologies, whether market reforms will come about to ensure financial returns for these projects into the future, as well as how well governmental agencies are able to set requirements for curbing hydrocarbon use and how well they're able to meet these self-imposed requirements.

The following is a figure that depicts the three carbon pricing policy schemes that are supposed to aid efficiency increases to fit within the 450 ppm scenario: [61]

Figure 11: Co2 price assumptions in selected regions by scenario.

	Region	Sectors	2020	2030	2040
Current Policies Scenario	European Union	Power, industry and aviation	20	30	40
	Korea	Power and industry	20	30	40
New Policies Scenario	European Union	Power, industry and aviation	22	37	50
	Chile	Power	7	15	24
	Korea	Power and industry	22	37	50
	China	All	10	23	35
	South Africa	Power and industry	7	15	24
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry*	10	75	125

* All sectors in China.

(IEA, n.d.)

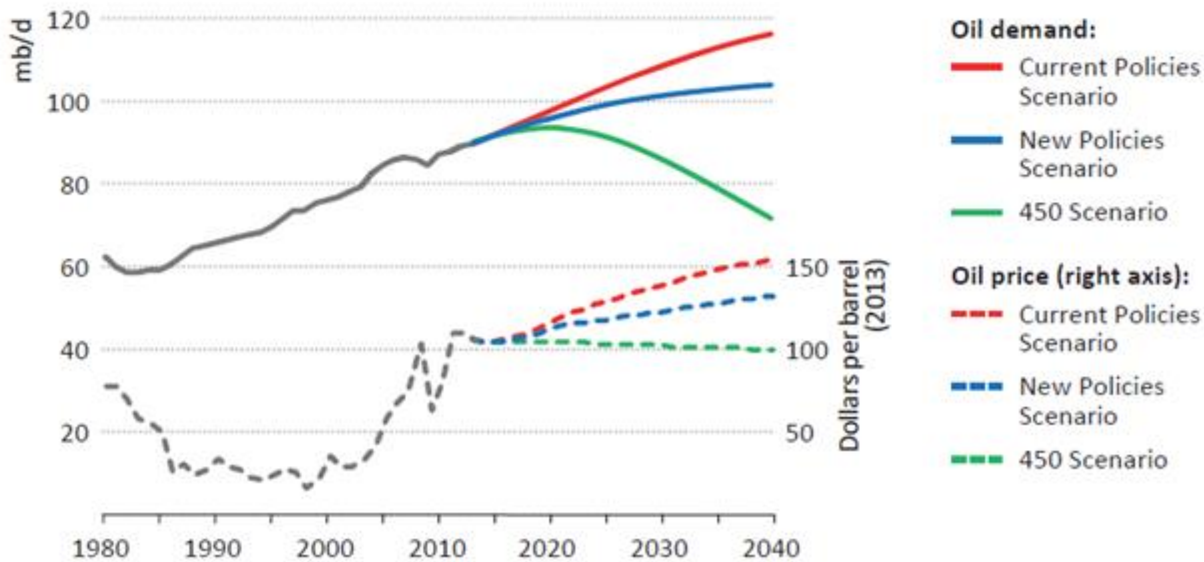
Of interest is the large spread in carbon prices between the years 2020 and 2040 for each of the three scenarios and how these prices compare to current carbon prices which range range from $5 to

[61] Ibid.

$30 depending on the sector and the climate policies of the region[62]. While a price of $30 may suggest that the projected goal of $140 may be a possibility, it's actually misleading because internationally a set price scheme has not been decided upon, real movements for establishing a market aren't gaining traction, and the high end price of $30 is actually an outlier.

The three scenarios depict greatly different price per barrel that can be expected for the year 2040. How expensive the selling price is will determine which of the many sources these hydrocarbons are retrieved from. At higher net prices the more technically demanding resources are accessible. At lower net prices the more easily accessible and cheaper options will be sought after. This shift away from more expensive resources could cause great impacts in geopolitics and energy security. The following figure describes the trends expected to be experiences with changes in energy and international policies impacting changes in oil net prices:

Figure 12: World oil demand and oil price by policy scenario



(IEA, n.d.)

In the most conservative of policy considerations shown by the green lines in the figure above, the net price per barrel is expected to level off and possibly even face a decline to prices around $100 dollars per barrel, this is a much lower net price than the those believed to be possible in the less stringent climate policy schemes modeled by the blue and red lines. In a world where climate policies are being rigorously pursued, disincentives are imposed on the burning of hydrocarbon intensive energy

[62] "Pricing Carbon," accessed April 17, 2015, http://www.worldbank.org/en/programs/pricing-carbon.

sources, thereby increasing the prices paid for the resources by consumers, while decreasing their profitability to suppliers. As mentioned earlier, if profits are decreasing the energy industry will make sound decisions to shift extraction away from risky or pricy investments.

Discussion

In evaluating the Arctic's ability to support hydrocarbon exploration we've examined three distinct reference frames: the environmental concerns, energy market projections, and policy uncertainties. Any one of these three heavily influences decisions both for facilitating and inhibiting the development of Arctic oil and gas.

The Arctic environment is a unique and captivating place abundant with biological activity and life. While the region is very small compared to the entire earth's surface and is occupied by only a few people from only eight countries, the Arctic is heavily impacted by and impressed up on by those outside the region. On a global scale, the arctic represents the greatest of climate change impacts, and exhibits the paradox of the decision to burn fuels and or save the environment. Regionally the Arctic is linked by cultures, by migratory animals that are heavily adapted to the polar climate, as well as the massive hydrocarbon resources. If one country were to become active within their region effects could very easily be felt throughout. These effects are very concerning considering on the individual national level significant infrastructure is lacking to properly and safely support these extractive industries.

The energy market projections into the distant future are clear about one thing, more energy will be needed to drive a growing population that is seemingly insatiable for development. However, which energy resources are favored for development are highly tied to the current prices for developing these resources. If prices are high then suddenly riskier or more technologically expensive projects are enticing enough to develop, and also, if prices are to drop to low values, then the market reevaluates the current projects and favors those that are less expensive to develop and are safer commitments.

Finally the policies that develop in the near and distant future to combat climate change are unclear and possibly unrealistic. While it may be a great exercise to model what a perfect world would look like in addressing the burning of carbon intensive fuels, if the international political systems are not cooperating accurately to stimulate successful and beneficial change, then the models are without significance.

Conclusion

The environmental concerns of developing arctic hydrocarbon reserves are great because of risks posed to ecologically and biologically sensitive regions, preexisting challenges from climate change, and other possible negative impacts from human development. As well as countries within the Arctic are simply unprepared to respond to an event in the face of a disaster such as an oil spill. The energy market will need hydrocarbons well into the future, but in a world where we're to responsibly consider our energy consumption with the impacts of climate change, attentions are expected to shift away from the expensive and risky Arctic reserves. And finally, with an uneasy playing field due to unclear international policy regimes, further disincentives exist for expensive and risky investments. In evaluating the facilitating incentives and inhibiting concerns of the Arctic hydrocarbon reserves, it is in the collective global interest if we all left the Arctic hydrocarbons alone.

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